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Description and bioacoustics of three new *Eurycorypha* (Orthoptera, Tettigonioidea) species from Tanzania and Ghana, with notes on their biology

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Abstract

Three new species of *Eurycorypha* Stål, 1873 are described, originating from Tanzania and Ghana. *E. willschi* from Ghana is widespread throughout central and west Africa, while the two species from Tanzania, *E. spicula* and *E. paraspicula*, are restricted to specific mountain ranges within the Eastern Arc Mountains. Two of the species were reared from nymphs, providing valuable data on their nymphal development and diet. The male songs represent amplitude patterns previously unknown in the bioacoustically hyperdiverse genus *Eurycorypha*. In the two species with known duets, the females were found to respond shortly after the male songs, while in *E. willschi*, they responded only after one of the two elements of the male song. How habitat drives speciation even in fully alate species is discussed, reflecting the extent and isolation of certain habitats. The wing shape of *Eurycorypha* species also appears influential; rounder, less flight-active species tend to be more restricted than elongate species in expansive habitats.

Keywords

Africa, biology, duets, habitat, songs, speciation

Introduction

Eurycorypha Stål, 1873 is the most species-rich genus of African Phaneropterinae. It is restricted to the mainland, the Arabian Peninsula, and Madagascar and comprises 55 species at present. While the genus contains widespread species, many are restricted to specific areas or even endemic to certain mountainous regions. Unpublished museum studies of CH and BM indicate that the number of species may be much higher than currently believed. While collected material of the morphologically similar species cannot easily be identified, *Eurycorypha* is famous for extremely diverse songs (Heller and Hemp 2020) and its nymphs imitating different species of ants (Hemp 2021). These characters are typically not available from collections. An overview of some East African species is provided in Hemp (2021), offering insights into their biology, distribution, and phenology. Information on chromosomes and bioacoustics for some species is provided in Hemp et al. (2013) and Heller and Hemp (2020).

The genus *Eurycorypha* is relatively uniform in its habitus. All species are green or green with lighter venation and exhibit either an elongate or more rounded body shape. An exception is found in *E. punctipennis* Chopard, 1938, which is predominantly yellow in males and yellowish-green in females, with a conspicuous pattern of speckles and dark spots covering most of the body. *Eurycorypha* is characterized by a broad fastigium verticis, oval eyes, and thin antennae. The tympana are open in all species, except for *E. ornatipes* Karsch, 1890, which exhibits a transitional form with partially closed tympana on the inner side of the forelegs. The 10th abdominal tergite of males holds significant diagnostic value. It can either be undifferentiated, with a straight or nearly straight posterior margin, or differentiated into various shaped processes. The cerci also exhibit considerable variability, ranging from slender tapering forms to thick, short, very small, laterally expanded, or even branched structures. The subgenital plate in males typically varies in shape but is usually elongated, broader at the base, and has a median incision that forms two short lateral processes, with or without styli. Deviations include subgenital plates that are broad and shield-like, very narrow, or with long lateral processes. In females, the subgenital plate exhibits the greatest variation in shape and often features lateral ridges, bulbs, or finger-like processes. The ovipositors are generally well-developed, being strongly upcurved or more elongated and slender, and are reduced in only one species, *E. ornatipes*.

Here, we describe three more new species, providing information on their biology and bioacoustics. We discuss speciation mechanisms applying to fully alate Orthoptera. In addition, the previously unknown duet of *Eurycorypha binasuta* is described and figured.

Material and methods

Identification.—The material was checked against the entomological collections of various European museums and the personal collections of the authors.

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Measurements.—Mounted specimens were measured with a digital calliper (precision 0.01 mm); the following measurements were taken (in mm): total body length: midline length of the insect from fastigium verticis to tip of the abdomen including the subgenital plate (in females, the ovipositor is not included in the measurement of the body length); pronotum length and depth; tegmina: length and maximum width of tegmina; hind femora length; ovipositor: measurements taken laterally from tip to base not including the curvature.

Images.—Specimens were photographed with a Nikon Coolpix 4500 digital camera mounted on a Wild M3 Stereomicroscope and with an Olympus Stylus TG-5 Tough (cf. Mertens et al. 2017); photos were integrated using the freeware CombineZP (Hadley 2008) and processed in Adobe Photoshop CS4.

Bioacoustics.—Sounds from 3 species and 17 specimens (4 male *E. paraspicula*; 3 males, 3 females *E. spicula*; and 3 males, 4 females *E. willschi*), captured in Tanzania and offspring of specimens from Ghana, were analyzed (approximately 53.3 h of recording: 0.5 h, *E. paraspicula*; 12.7 h, *E. spicula*; and 40.1 h, *E. willschi*). From *E. binasuta*, 2 males and 3 females (TANZANIA: Nguru Mt., above Dibago/Maskati, 1 i – 31 iii 2022, coll. C. Hemp) were recorded (13.6 h).

The male calling songs were recorded in the laboratory using a digital bat detector (Pettersson D1000X) with a sampling rate of 100 kHz. The singers were caged in plastic tubes or gauze cages with a microphone fixed or handheld at distances between 5 and 60 cm. Female response behavior was studied in the laboratory using virgin females reared from field-collected nymphs or from eggs. Duets were recorded in stereo using a Sony PC-62 microphone (frequency response relatively flat up to 30 kHz according to our tests) and an Uher M645 audio microphone connected to a personal computer through an external soundcard (Transit USB, "M-Audio"; 64 kHz sampling rate). A male and female were placed separately into two plastic tubes (Drosophila tube 28.5 × 95 mm, Biosigma, Cona, Italy) usually standing side by side, with one microphone placed inside or on top of each vial. Typically, both microphones picked up male and female sounds but with different amplitudes. Song measurements were obtained using Amadeus II and Amadeus Pro (Martin Hairer; http://www.hairersoft.com). Oscillograms of the songs were prepared using Turbolab (Bressner Technology, Germany), typically after 1 kHz high-pass filtering. Recordings were made at temperatures between 20°C and 25°C. Data are presented as mean ± standard deviation. For spectral analysis, short song parts (echemes or syllables) were analyzed using the mean of 512 point-wide Hanning windows overlapping by 100 points. Examples of the songs will be deposited in the OSF.

The stridulatory files were evaluated from photos taken with a Sony Cybershot DSC-P120 on an Olympus SZ Binocular Stereo Zoom Microscope, using Adobe Photoshop.

Acoustical terminology.—Tettigonioids stridulate by opening and closing their tegmina. The sound resulting during one cycle of movements is called a syllable, often separable in opening and closing hemisyllables (Ragge and Reynolds 1998). Syllable duration: time period measured from the beginning of the first impulse to the last; syllable period: time period measured from the beginning of a syllable to the beginning of the next (reciprocal value: syllable repetition rate, SRR); echeme: first-order assemblage of syllables (duration, period, and rate as for syllable); pulse: undivided train of sound waves increasing in amplitude at the beginning and containing several similarly sized wave maxima and minima; impulse: a simple, undivided, transient train of sound waves (here: the damped sound impulse arising as the effect of one tooth of the stridulatory file); latency time: interval between the beginning of a male song or of a trigger syllable in the male song to beginning of female response.

Results

Taxonomy

Order Orthoptera Olivier, 1789
Family Tettigoniidae Krauss, 1902
Subfamily group Phaneropteridae Burmeister, 1838
Subfamily Phaneropterinae Burmeister, 1838
Tribe Amblycoryphini Brunner von Wattenwyl, 1878

Genus *Eurycorypha* Stål, 1873

Type species.—*Phylloptera cereris* Stål, 1873.

***Eurycorypha paraspicula* sp. nov.**

https://zoobank.org/D78AFE3A-817B-4CDE-B420-AECC881218F6

Material examined.—**Holotype:** ♂; TANZANIA • East Usambara Mountains, Nilo Forest Reserve; 1500 m; montane forest; February 2021; CCH. **Paratypes:** 3♂; TANZANIA • same data as holotype; CCH • 1♂, same data as holotype; March 2021; CCH.

Description.—**Male.** General habitus and color. A medium-sized species with a distinctly roundish appearance (Fig. 1A, B). The tegmina display a pattern of white to yellowish veins on a dark green ground color. The rest of the body is speckled yellowish-green. In life, yellow fasciae are visible on the head and body. Head and antennae: Antennae thin, typical of *Eurycorypha*, reaching approximately to the tips of the flexed tegmina. Fastigium verticis about twice as wide as the scapus of the antenna; it meets the equally broad fastigium frontis along a well-developed horizontal line. The face bears callose carinae, yellow when alive. Eyes elongate and oval, typical for the genus. Thorax: Pronotal disc flat and smooth; anterior margin broadly incurved, posterior margin broadly rounded. Wings: Tegmina very roundish, about 2.3 times longer than broad; hind wings (alae) hardly visible. Legs: Fore coxa with a short, stout spine. Fore and mid femora dorsally unarmed; ventrally with 3–4 outer spines, lacking inner spines. Hind femora with 5–8 irregularly spaced spines near the apex on the ventral side. Fore and mid tibiae with a ventral double row of numerous spines. Hind tibiae with four rows of spines and three slender spurs on each side. Abdomen: Last abdominal tergite bearing two slender and sharply pointed spines at the posterior margin (Fig. 1B, D). Cerci thick at the base, tapering toward rounded apices, each with a distinct sclerotized ridge (Fig. 1C–E). Subgenital plate broad at the base, narrowing posteriorly; posterior margin incised, forming two short lateral processes; styli present (Fig. 1E).

Female.—Unknown.

Measurements.—(in mm) Males (n = 5) Total length: 30.3–31.8; body length: 18.2–22.7; pronotum length: 4.8–5.2; pronotum depth: 3.9–4.3; length of tegmina: 24–26.7; width of tegmina: 10.0–11.0; length of hind femur: 16.5–17.7.

Habitat and notes on biology.—Montane forest at around 1500 m.a.s.l. Currently, this species has been collected only at the highest points of the East Usambara Mountains in the Nilo Forest Reserve. Despite

regular visits to this area (19 times between 2012 and 2024), no females have been encountered. Similar to other montane Orthoptera species, it is likely present only during the warmer times of the year.

Distribution.—Tanzania (East Usambara Mountains).

Diagnosis.—Males of *E. paraspicula* are characterized by an unusually roundish habitus, which is uncommon within the genus. This species is morphologically most similar to *E. spicula* from the Nguru Mountains, but can be distinguished by the more rounded shape of the male body, longer paired spines on the posterior margin of the tenth abdominal tergite, and notably thicker cerci. The male cerci of *E. paraspicula* are robust and terminate in a distinct sclerotized ridge, whereas in *E. spicula* they are more slender with narrower tips. Most significantly, the acoustic signals of *E. paraspicula* differ from those of *E. spicula*, providing a reliable means of species recognition. The female of *E. paraspicula* is currently unknown.

Bioacoustics.—The male song consists of groups of polysyllabic, crescendoing echemes (Figs 8A, 9A). An echeme contains 7.7±0.5 syllables (4 males; 68 measurements; range 5–9), produced at an SRR of 41 Hz corresponding to a syllable period 24.4±0.8 ms (range 20–28 ms; T = 24–25 °C). One group of echemes typically contains 1.9±0.3 elements (4 males; 35 measurements; range 1–3), repeated at periods of 1.56±0.56 s (4 males; 37 measurements; range 1.2–2.4). These groups are separated by intervals of 8.7±1.6 s (4 males; 32 measurements; range 4.6–24.2) from the next. The spectrum of the song shows a relatively narrow peak around 13 kHz (Fig. 11; see Table 1 for other details). Stridulatory file, tooth number, and tooth intervals are in the range typical for *Eurycorypha* (Table 1; for comparison, see Heller and Hemp 2020).

***Eurycorypha spicula* sp. nov.**

https://zoobank.org/4CB4A077-DAB8-4615-86D0-DF1FE863B85D

Material examined.—**Holotype:** TANZANIA • ♂; Nguru Mts; 1900 m a.s.l.; montane forest above Dibago/Maskati; November 2021; CCH. **Paratypes:** • 11 ♂, 11 ♀; same data as holotype; CCH.

Description.—**Male.** Habitus and color. A roundish medium-sized species, green with lighter veins on the tegmina and speckled with white dots and patches on pronotum and head (Fig. 2A). Color pattern white to yellowish veins on dark green background on the tegmina, rest of body also speckled yellowish-green. Head and antennae: Antennae typical of *Eurycorypha*, thin, about as long as flexed tegmina. Fastigium verticis about 2.4 times as wide as scapus of antenna; fastigium verticis meeting equally broad fastigium frontis along a well-developed horizontal line; face with callose frontogenal carinae, yellow when alive; eyes typical for *Eurycorypha*, elongate and oval. When alive, with yellow fasciae. Thorax: Pronotum with flat and smooth disc, anterior margin of pronotum broadly incurved, posterior margin broadly rounded. Wings: Tegmina roundish, only about 2.5 times longer than broad; alae only slightly protruding. Stridulatory file comparatively long, evenly curved, and about 2.2 mm long, consisting of very densely packed teeth. Legs: Fore coxa with very short, broad-based spine. Fore and mid femora dorsally unarmed, ventrally with 2–4 spines on outer side and without inner spines. Hind femora ventrally with 4 spines at apical end. Fore and mid tibiae with ventral double row of few spines (3–8). Hind tibiae with 4 rows of spines and three spurs at each side. Abdomen: Last abdominal tergite with two broad-based short spines at posterior margin (Fig. 3A). Cerci thick at base, narrowing to their apices and ending in a sclerotized small ridge (Fig.

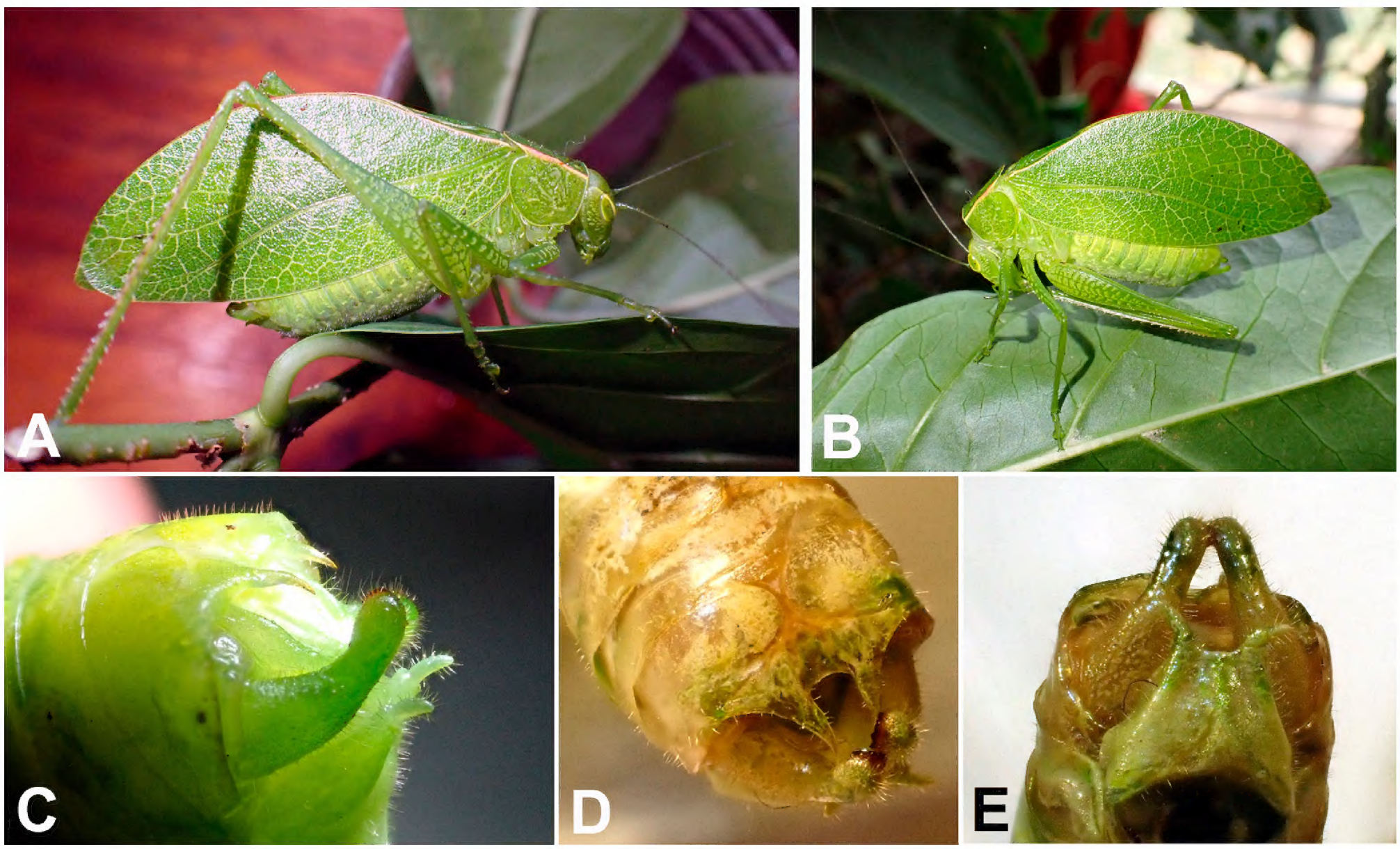

Fig. 1. *Eurycorypha paraspicula*. **A, B.** Male; **C.** Lateral view of male abdominal apex of alive specimen; **D.** Dorsal view of male abdominal apex; **E.** Ventral view of male abdominal apex with subgenital plate.

3A, C, E). Subgenital plate with broad base. Posterior margin incised forming two short processes with small styli (Fig. 3C).

Female.—Very roundish and compact, of same color pattern as male (Fig. 1B). Ovipositor well-developed, upcurved (Fig. 3B). Subgenital plate forming a triangular flap. Lateral margins of the lower valves are thickened, running in parallel to the subgenital plate and forming an ear-like grove or hole lateral at base of pronotum (Fig. 3B, D, F).

Nymphs.—The first stages resemble black ants, gaining more color in stages two and three (Fig. 2C, E). Unlike most other *Eurycorypha* species where nymphal stages are known, the nymphs of *E. spicula* are dorsally black on the head, the pronotum, and the abdomen, and the legs are partly black. The black coloration persists in the last two stages four and five (Fig. 2F) and vanishes when molting to the adult, which is predominantly green (Fig. 2A, B). Eight nymphs (L1–L3) were collected in November

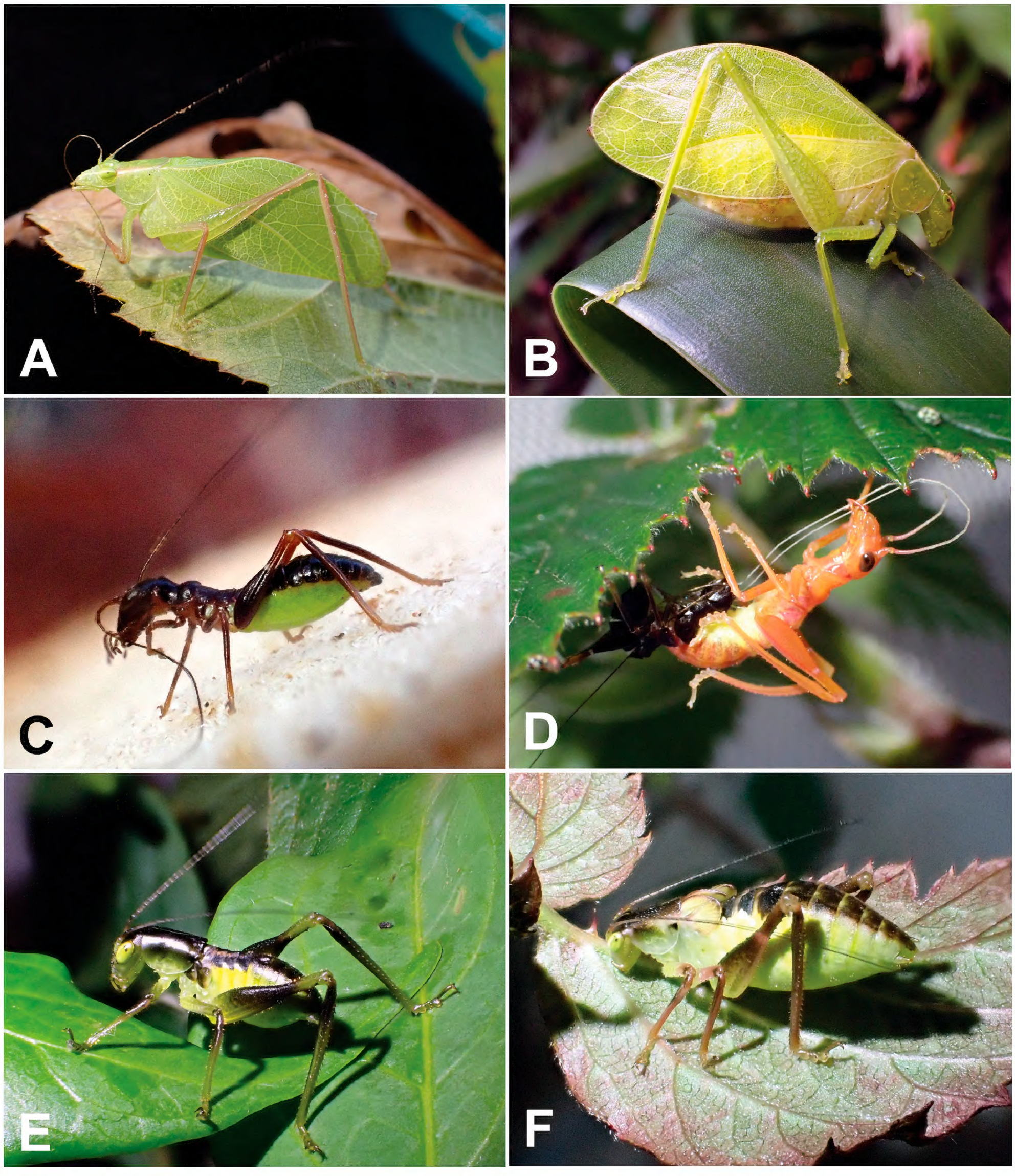

Fig. 2. *Eurycorypha spicula*. **A.** Male; **B.** Female; **C.** Second instar; **D.** Molting from L1 to L2; **E.** Third instar; **F.** Fourth instar.

Table 1. Dimensions of stridulatory file and spectral characteristics of songs.

Species	File length (mm)	Tooth number	Tooth spacing in middle (µm)	Peak frequency m/f (kHz)	Bandwidth 10 dB below peak m/f (kHz)
E. paraspicula	2.2 (n = 4)	90 (n = 1)	32	12.8/ n.a.- (n = 4)	4.1/ n.a.- (n = 4)
E. spicula	1.8 (1.7–2.5; n = 6)	75 (n = 1)	25	13.3/11.6 (n = 3)	8.2/9.3 (n = 3)
E. willschi	2.0 (n = 1)	97 (n = 1)	21	16.5/14.5 (n = 3)	6.8/12.6 (n = 3)
E. binasuta	1.8*	110*	22*	10.9; 10.5$/11 (n = 1)	6.2;2$/1.9 (n = 1)

* from Heller and Hemp 2020; $ groups of syllables; pulse-like syllables; n.a. not available.

2024 at the same locality as in 2021, suggesting that this species hatches in November, coinciding with the onset of the short rains and rising temperatures.

Biology.—L1 and L2 nymphs were collected in November 2021 from a flowering *Bidens kilimanjari* at an elevation of about 1900 m a.s.l. in the Nguru Mountains above Dibago/Maskati. They were taken to the laboratory and reared to adults on various leaves from trees and bushes at Mt Kilimanjaro. The first adults emerged on the 12th of January 2022. Thus, as in most other *Eurycorypha* where development time from hatching to the adults is known, *E. spicula* takes about 2 months from hatching to the adult.

Some specimens were infected by Nematoida while reared in the lab. Fig. 4 shows a nematoid approximately 10 times the length of the insect that emerged from an adult female of *E. spicula*.

Measurements.—(mm). Males (n = 13). Total length: 27.2–32.6; body length: 12.7–19.3; pronotum length: 4.1–4.6; pronotum depth: 3.1–3.5; length of tegmina: 20.8–27.1; width of tegmina: 9.2–10.6; length of hind femur: 13.4–15.2. Females (n = 9). Total length: 27.1–28.7; body length: 15.7–16.9; pronotum length: 4.2–4.8; pronotum depth: 3.2–3.7; length of tegmina: 22.7–24.6; width of tegmina: 9.5–11.5; length of hind femora: 13.9–16.6; ovipositor: 5.5–5.6.

Diagnosis.—Males of *E. spicula* are somewhat roundish but less so than in the closely related *E. paraspicula*. They are distinguished by the presence of two relatively short spines at the posterior margin of the tenth abdominal tergite, and slender, tapering cerci with narrow tips that end in a small sclerotized point. Although morphologically very similar to *E. paraspicula*, the male of *E. spicula* can be differentiated by its more elongated appearance and less robust cerci. The female is known and displays a compact, roundish habitus, a well-developed upcurved ovipositor, and a triangular subgenital plate bordered by thickened ridges.

Bioacoustics.—The male song consists of complicated and quite characteristic echemes. One relatively long syllable is followed by a series of shorter elements (Figs 8B, 9B). Surprisingly, some parameters of these echemes were quite variable in the three recorded males. The duration of the long syllables varied between 38.4 and 84.4 ms, the number of short syllables ranged between 6.8 and 11.8, and variation of the duration of the complete echeme was also not small (324–441 ms; all means of 3 males; n = 10 per male; T = 21 °C). More constant were the periods between the beginning of the long syllable and that of the series of short syllables (138–152 ms) and between the short syllables (28.5–31 ms corresponding to 32–35 Hz SRR; measured from the beginning of the 5th to that of the 6th syllable). The echemes were repeated at intervals of several seconds. When two males were singing in acoustical contact, the structure of their echemes became more irregular ('leader' in Fig. 10A, B; upper line), while the other ('follower' in Fig. 10; lower line) placed his echemes immediately after that of the first. Occasionally the leader also produced long series of short syllables.

The first answer of females was recorded approximately 417±27 ms (mean±SD; n = 10) after the beginning of the echeme, 281±27 ms after the beginning of the syllable series, and 76.5±30 ms after the end. However, in other situations (e.g., when several males were singing), the females responded more variable with latencies of the first response very close to the end of the male echeme (0.6±50.1 ms – 2.6±35.6 ms). The amplitude modulation of their response was also very variable, from single impulses (Fig. 9B) to series of impulses, probably produced by repeated tegmen movements (Fig. 9C). If they were not answers to their own songs, males reacted to these sounds, sometimes by producing a series of short syllables (Fig. 9C). See the discussion for the function of the parts of the song.

The spectrum of the male song showed a broad peak around 13 kHz; that of the female was similar but even broader (Fig. 11; see Table 1 for other details). Male stridulatory file, tooth number, and inter-tooth intervals are in the range typical for *Eurycorypha* (Table 1; for comparison, see Heller and Hemp 2020).

Eurycorypha willschi sp. nov.

https://zoobank.org/58CADD3A-D6B3-436F-99C0-ACD108340520

Material examined.—**Holotype:** IVORY COAST • ♂; Comoé, Zamou; 10 Nov. 2014; light trap; leg. P. Moretto; MNHN. **Paratypes:** IVORY COAST • 1♂; same locality as holotype; 31 May 2016; light trap; leg. P. Moretto; MNHN • 2♂; same locality as holotype; 2 Nov. 2016; light trap; leg. P. Moretto; MNHN.

Additional material examined.—IVORY COAST • 1♀; M'Banto; 6–8 Jul 2013; light trap; leg. P. Moretto; MNHN • 2♀; Comoé, Zamou; 2–10 Apr 2016; light trap; leg. P. Moretto; MNHN • 2♀; Comoé, Zamou; 19–22 Jun. 2017; light trap; leg. P. Moretto; MNHN • 1♀; Boudoukou, Zamou; Jul 2004; light trap; leg. P. Moretto; MNHN • 2♀; Kolomabira; 5 Jun 2016; light trap; leg. P. Moretto; MNHN • 1♀; Kolomabira; 2 Nov 2016; light trap; leg. P. Moretto; MNHN • 2♀; Mt. Tonkoui; 20 Jun 2015; light trap; leg. P. Moretto; MNHN • 2♀; Mt. Tonkoui; 17 Oct 2015; light trap; leg. P. Moretto; MNHN • 1♀; Mt. Tonkoui; 11 May 2017; light trap; leg. P. Moretto; BMPC • 1♀; Lamto, Toumodi, RBAP Bouhinta; 26 Jul 1962; MNHN • 1♀; Lamto; 15–16 Feb 1969; coll. C. Girard; MNHN • 9♂, 4♀; Lamto (Toumodi); various dates: 20 Mar 1968, 15–30 Oct 1968, 15–21 Jan 1969, 1–12 Nov 1968, 20–30 Jul 1968, 14 Feb 1969, 15–25 Jul 1968, 15–30 Sep 1968, 24–31 Mar 1964, 24–31 Mar 1994, Nov 1966; coll. C. Girard; MNHN. • 1♀; Lamto (Toumodi), RBAP, Bauhinia; 25 Jul. 1952; coll. Paul Planquilte; MNHN. CENTRAL AFRICAN REPUBLIC • 1♂; La Maboké; Sep 1963; coll. R. Pujol; MNHN. NIGER • 1♂; Haut Niger et Benque; Ward 159-96; MNHN. BURKINA FASO • 1♂; Nazonga, Savane; 18–25 Oct 1986; coll. N. Berti & Cl. Girard ; MNHN. BURKINA

FASO (Upper Volta) • 1♂; Bobo; 3 May 1966; coll. Gamontellgrie; MNHN. GUINEA • 1♂; Nimba; Dec 1956–May 1957; leg. Lamotte, Amiet; coll. Vanderplaetsen; MNHN • 1♀; Nimba; Feb–Jun 1942; MNHN • 1♀; Kindia, Damakanya; 29–30 Jan 1951; coll. Bechyne; MNHN. BENIN (Dahomey) • 1♀; Ouidah; 1925; coll. Millet-Horsin; MNHN. NIGERIA • 1♂; Azare; Oct 1928; coll. Dr. Li Lloyd; NHM. CAMEROON • 1♀; Obout; 29 Jul–12 Aug 2023; coll. A. Willsch. GHANA • 3♂, 5♀; Larabanga, near Mole National Park; 16–18 Oct 2022; coll. A. Willsch; CCH.

Description.—**Male.** General habitus and color. A medium-sized, elongate species, predominantly green, with a faint pattern of white and yellowish, irregularly distributed veins on the tegmina. The head, pronotum, and body are green with whitish speckles, as observed in life (Fig. 5A). When preserved, the white-yellowish pattern fades (Fig. 6A). Head and antennae: Antennae typical of *Eurycorypha*, thin. Fastigium verticis approximately 2.2 times as wide as scapus of antenna; fastigium verticis meeting equally broad fastigium frontis along a well-developed horizontal line;

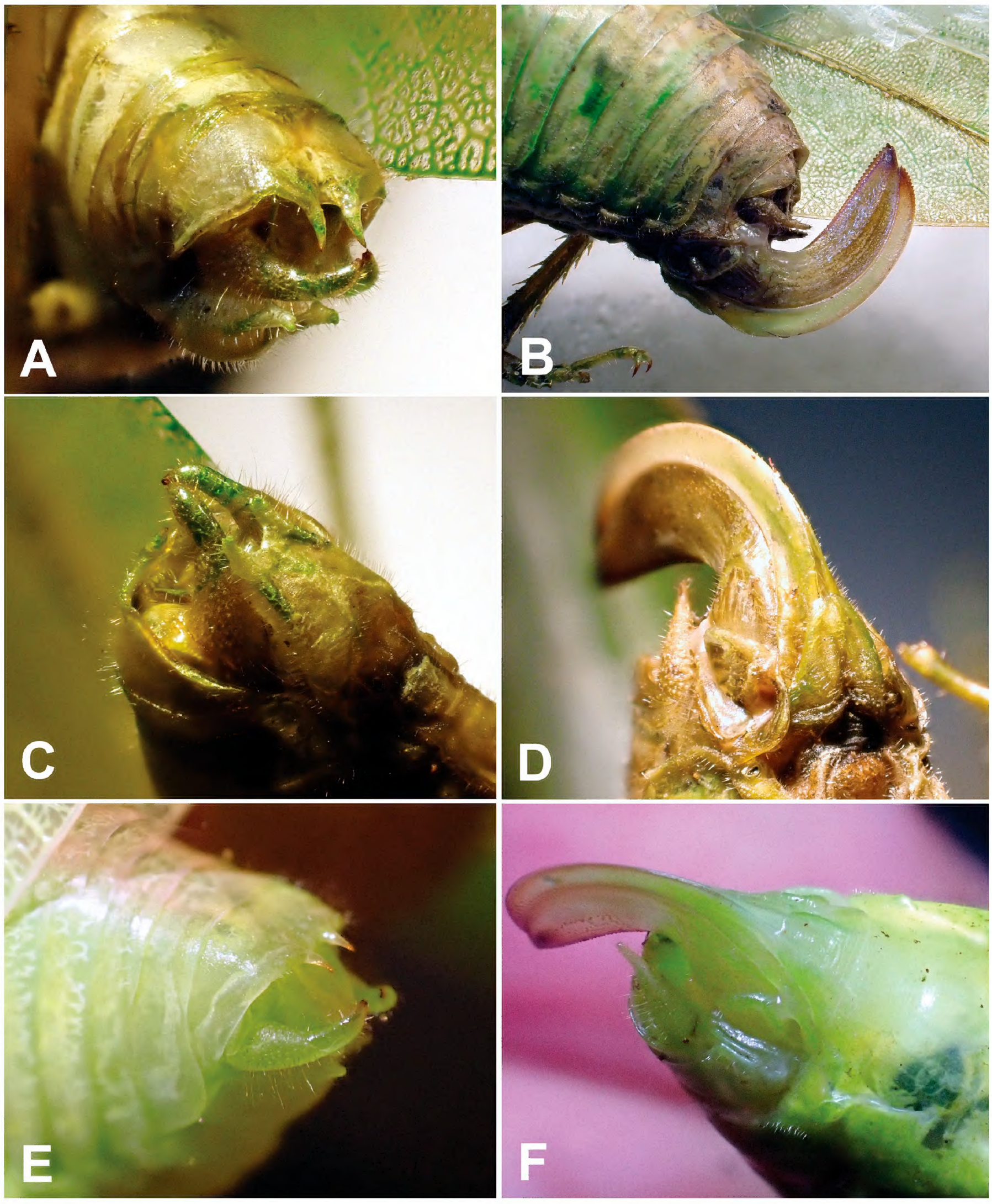

Fig. 3. *Eurycorypha spicula*. **A.** Semi-dorsal view of male abdominal apex; **B.** Lateral view of ovipositor; **C.** Semilateral view of male subgenital plate; **D.** Subgenital plate of female; **E.** Semilateral view of male abdominal apex of alive specimen; **F.** Subgenital plate of alive female specimen.

face with evident frontogenal carinae; eyes typical for *Eurycorypha*, elongate and oval. Thorax: Pronotum with flat and smooth disc, anterior margin of pronotum broadly incurved, posterior margin rounded, lateral carinae evident. Wings: Tegmina elongate, rounded at tips, 3.5–3.8 times longer than broad. ***Legs.*** Fore femora dorsally unarmed, ventrally with 3–4 spines. Mid femora with 3 ventral outer spines. Hind femora with 5–7 ventral outer and inner spines. Fore tibiae with an open tympanum on both sides, with a ventral double row of 4–5 spines; mid tibiae with ventral double row of 4–6 spines. Hind tibiae with double row of 18–20 spines at ventral side; 3 slender sclerotized spurs at each side. Abdomen: Last abdominal tergite elongated like a stylus, formed by two parallel running parts; apex separated into two wing-like tips, the lateral sides expanded anteriorly to form two large tightly attached lobes (Fig. 6B). From the underside, the two tips are nicely seen with a median oval part formed by the widened ventral margins of the structure that unite further anteriorly (Fig. 6C). Cerci broad and laterally compressed with an inner lobe or dent midway; tips of cerci forming two wide lobes; the whole cercus strongly hairy. Subgenital plate of normal shape, broad at base and tapering to its apex; posterior margin broadly incised forming two short lateral processes; without styli (Fig. 6C).

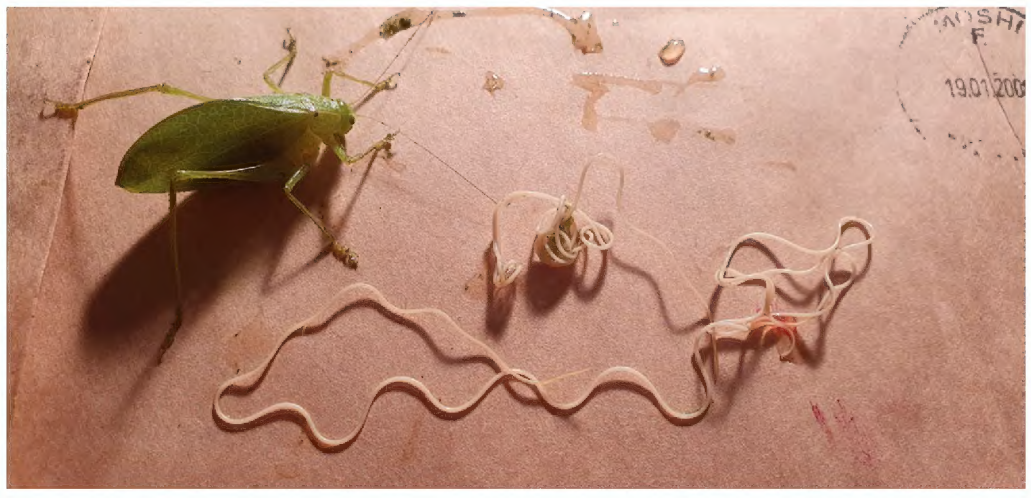

Fig. 4. Nematomorpha parasite emerging from adult female of *Eurycorypha spicula*.

Female.—As the male, but with broader tegmina being 3.4–3.5 times longer than broad (Figs 5B, 7A). Ovipositor well-developed and strongly upcurved. The subgenital plate is a triangular flap with an almost rounded posterior margin, only slightly indented in middle. Gonangulum longish, ventrally bulbous. The margins of the lower valves form a thickened ridge within which the ventral bulbous part of the gonangulum is embedded.

Nymphs.—As seen in many *Eurycorypha* species with known nymphal stages, the first three stages of *E. willschi* resemble black ants. The nymphs gain more green color while growing and in stage 4 begin to lose their ant-like appearance, changing to leaf camouflage (in Fig. 5C, three nymphal stages are seen together: L1, L2, and L4). Eggs are oval and black and are laid singly into the margins of leaves (Fig. 5D).

Measurements.—(mm). Males (n = 4). Body length: 18.8–22.1; pronotum length: 4.3–4.8; pronotum depth: 3.9–4.2; length of tegmina: 27.1–28.1; width of tegmina: 7.2–8.0; length of hind femur: 13.5–14.5. Females (n = 8). Body length: 20.3–21.6; pronotum length: 4.3–5.0; pronotum depth: 4.3–4.8; length of tegmina: 29.3–32.1; width of tegmina: 8.4–9.2; length of hind femur: 15.0–16.5; length of ovipositor: 6.0–7.0.

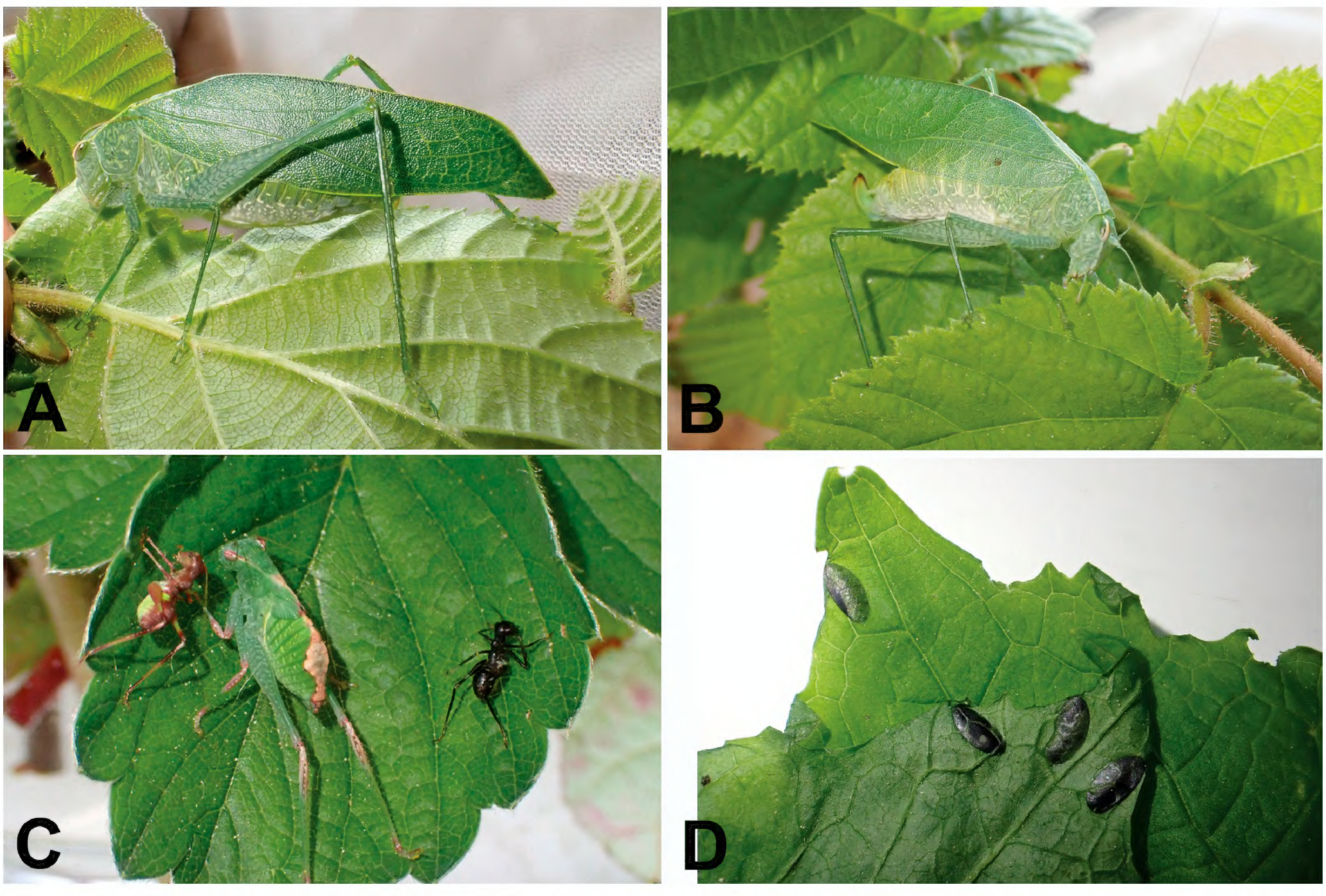

Fig. 5. *Eurycorypha willschi*. **A.** Male; **B.** Female; **C.** Nymphal stages; **D.** Eggs.

Diagnosis.—*E. willschi*, *E. stylata* Stål, 1873, and *E. stenophthalma* Chopard, 1963 are similar, differing in the males in the length of the stylus and the shape of the cerci (see images in OSF). They all have a distinct (but differently shaped) inner cercal tooth, missing in most *Eurycorypha* species (e.g., in all species known from East Africa). There are also new species belonging to this group of *Eurycorypha* species with a "stylus-like" 10th abdominal tergite. These species will be treated in a revision of the genus currently in preparation.

The females of *E. willschi* have widened margins of the ventral valves of the ovipositor that form ear-like structures when viewed from above, as well as having bulbous parts of the ventral gonangulum (Fig. 7B, C). Similar to *E. willschi* are the females of *E. stenophthalma* known from Chad that also have large bulbs beside the subgenital plate. The female of *E. stylata* is unknown. The male holotype of *E. stylata* was collected in Sierra Leone, and there are records also from Senegal (Hemp and Massa, in prep).

Etymology.—*E. willschi* is named after Mr. Achim Willsch, collector of the life specimens of this species in Ghana.

Distribution.—Widespread in West Africa.

Bioacoustics.—In the male song, two different elements were observed. At first glance, both are quite similar (see Fig. 8), but they differ in SRR and function. Typically, several (to many) similar elements were repeated one after another. One of these elements invariably consists of pairs of syllables (Fig. 9D; syllable period 34–38 ms; means of three males, n = 10–18 per male; SRR 26–29 Hz; T = 20–23 °C). The period of the pairs—called slow echemes—is quite variable (period 4–28 s; means of three males, n = 10–11 per male; range of measurements 2.7–65 s; T = 20–23 °C). These slow echemes could be heard for relatively long times (up to 10 minutes recorded). More typically, however, a male switched to a series of the other element after a shorter time. This element consisted of 2–3 syllables (Fig. 9E; syllable period 20–22 ms; means of three males, n = 18–23 per male; T = 20–23 °C), thus showing a clearly higher SRR (45–50 Hz); it is therefore called a fast echeme. Most of these series begin with elements of low amplitude and increase then in loudness (Fig. 11C).

The females responded exclusively after these fast echemes. Their responses occurred 63–86 ms (means of three females, n = 10–12 per female; T = 20–23 °C) after the beginning of the last (and loudest) syllable of the male echeme and 99–125 ms after the beginning of the first male syllable. Quite often the male added a series of very short syllables after the female's response, occasionally even when the female had not answered. See discussion for the function of the parts of the song.

The spectrum of the male song showed a broad peak around 16.5 kHz; that of the female was similar but even broader (Fig. 11; see Table 1 for other details). Male stridulatory file, tooth number,

Fig. 6. Male holotype of *Eurycorypha willschi*. **A.** Habitus; **B.** Lateral view on abdominal apex; **C.** Subgenital plate.

and inter-tooth intervals are in the range typical for *Eurycorypha* (Table 1; for comparison, see Heller and Hemp 2020).

Spermatophore.—During mating, the males transfer a spermatophore to the female as is typical for tettigonioids. At 51.5 mg (10% male body mass), the size of the spermatophore is typical for the genus (see Table 2 for comparative data mainly based on specimens studied by Heller and Hemp 2020).

Bioacoustics of *Eurycorypha binasuta* Hemp, 2017a

Description.—Eurycorypha binasuta is an elongate species of predominantly green colour. At the posterior margin of the 10th abdominal tergite of the male two short nose-like processes are typical. The male cerci are comparatively stout and short with a sclerotized dent at their tips. The subgenital plate of the male is elongate with two short lateral processes. As in most *Eurycorypha* species the stridulatory file does not serve for a characterization at species level. As in other *Eurycorypha* species it is slightly curved with numerous densely set teeth. The subgenital plate is of normal shape with two small laterally compressed processes at the posterior margin; without styli. The females have broader tegmina than the males. The ovipositor is well-developed and strongly upcurved as in most *Eurycorypha* species. The subgenital plate of the females is a narrow flap with an evenly rounded posterior margin.

Notes about the calling song of this species have been published earlier (Heller and Hemp 2020) but are based on very short recordings. Here we present more data on the male song and describe the male–female duet.

In the male song, two different types of echemes were observed, each with two sub-types. The most common one was a crescendoing group of syllables (sub-type A; Figs 8D, 12A) often followed by a few short pulse-like syllables (sub-type B; Figs 8E, 12B, G). These echemes were separated from the next by intervals typically larger than 10 s. The syllable group consisted of 7.9–9.4 (range 5–11) syllables produced with an SRR between 32 and 33 Hz (means of 2 males; 22–23 °C; n = 13–23; second last period measured). The last syllable varied considerably in amplitude modulation and duration. The short pulse-like syllables (n = 1.4–5.5; means of 2 males; range 1–8; n = 7–10) followed after an interval of around 200 ms (180–203 ms; range 152–283 ms). The other type of echeme consisted of pairs (sub-type A; Fig. 12E) or triplets (sub-type B; Fig. 12F) of syllables. After having heard female responses, the males produced this type of echeme only irregularly and rarely. However, it was heard relatively often by an isolated male (Heller and Hemp 2020).

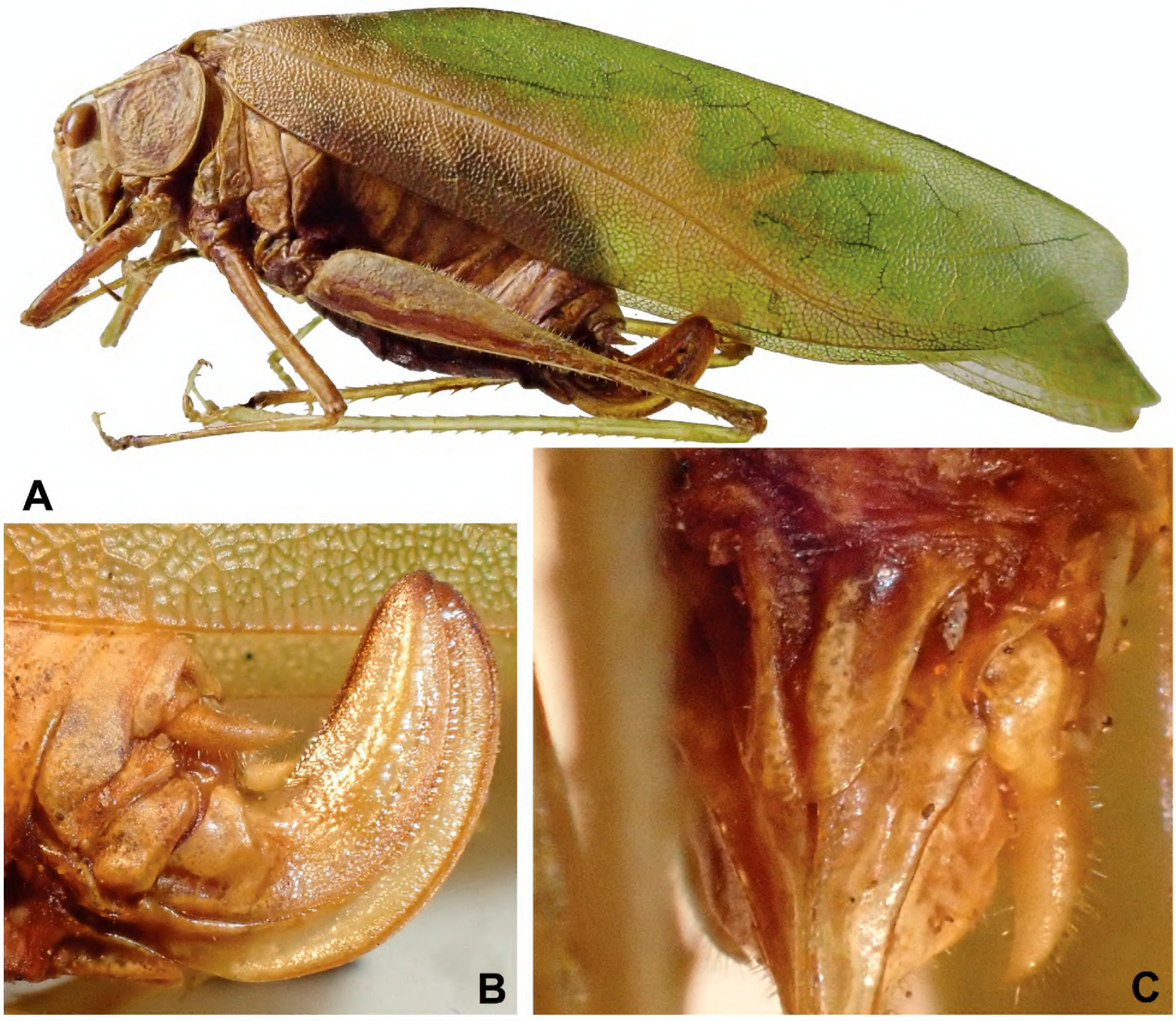

Fig. 7. Female paraytpye of *Eurycorypha willschi*. **A.** Habitus; **B.** Ovipositor; **C.** Subgenital plate.

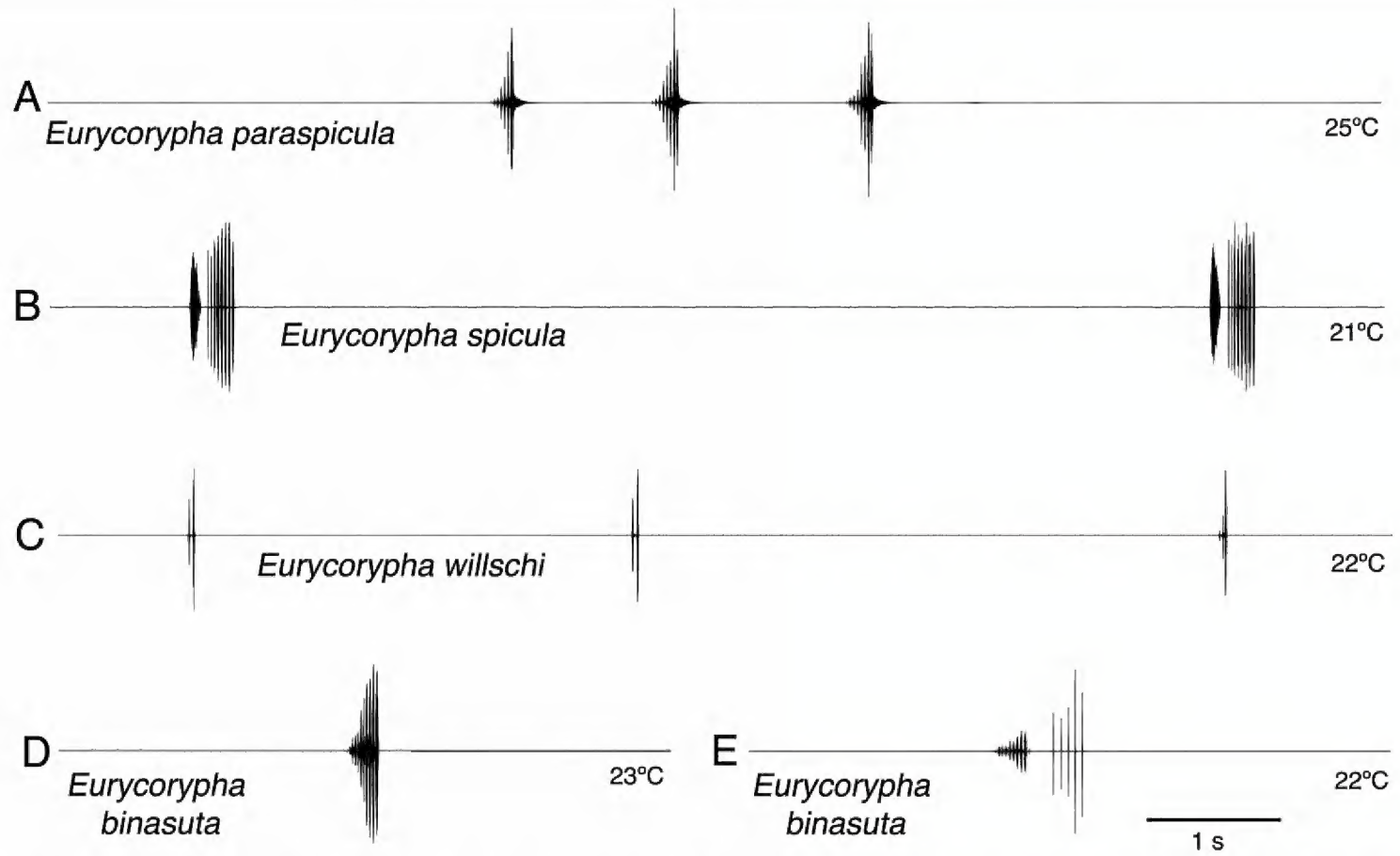

Fig. 8. Oscillograms of male calling songs, overviews (10 s sections). In *E. willschi*, two slow are followed by one fast echeme.

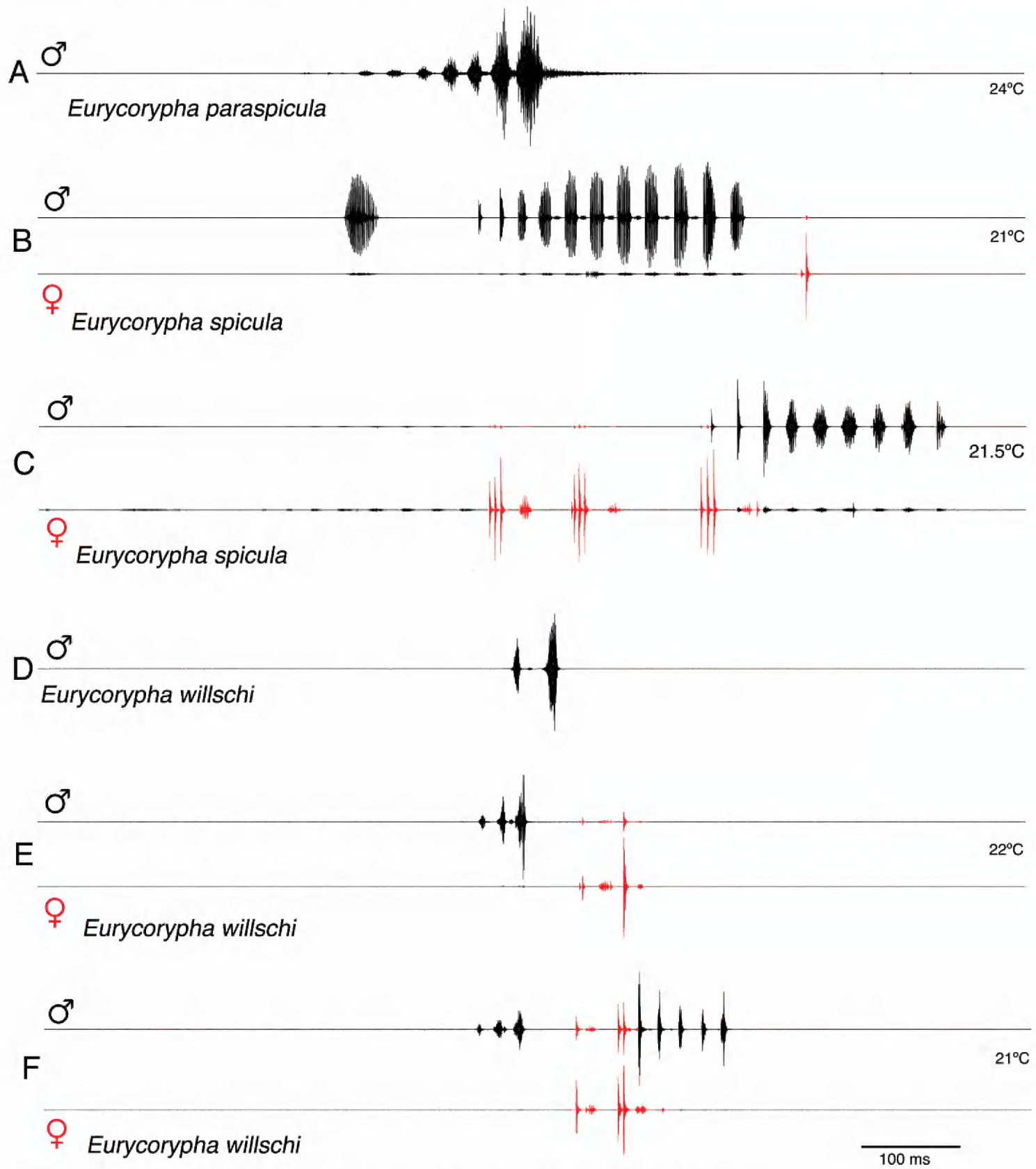

Fig. 9. Oscillograms of male calling songs and male–female duets, details (1 s sections).

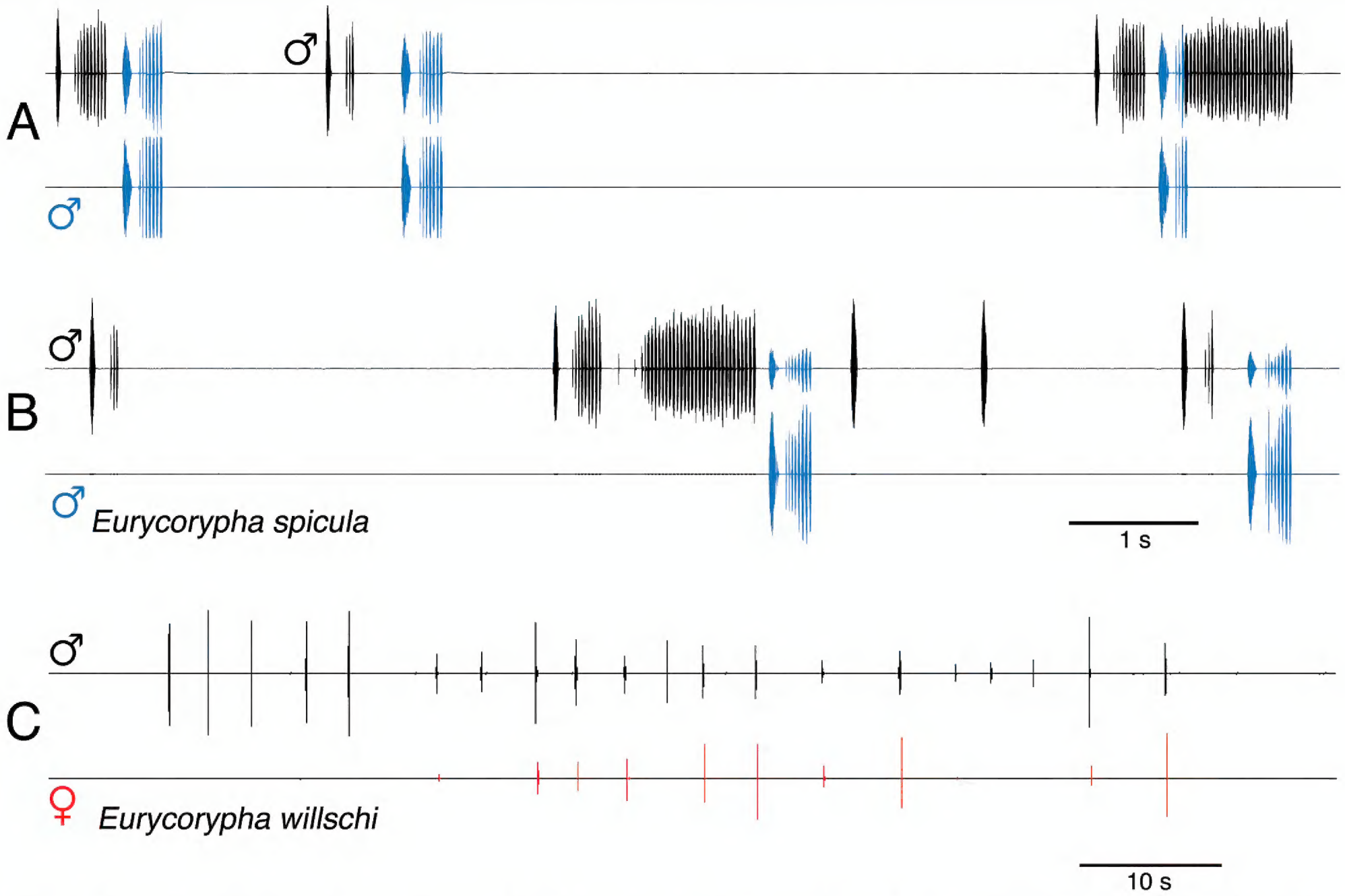

Fig. 10. Oscillograms of male–male interactions (**A, B.** Upper line leader, lower line follower; blue) and male–female duets (**C.** Five slow echemes followed by a series of fast echemes).

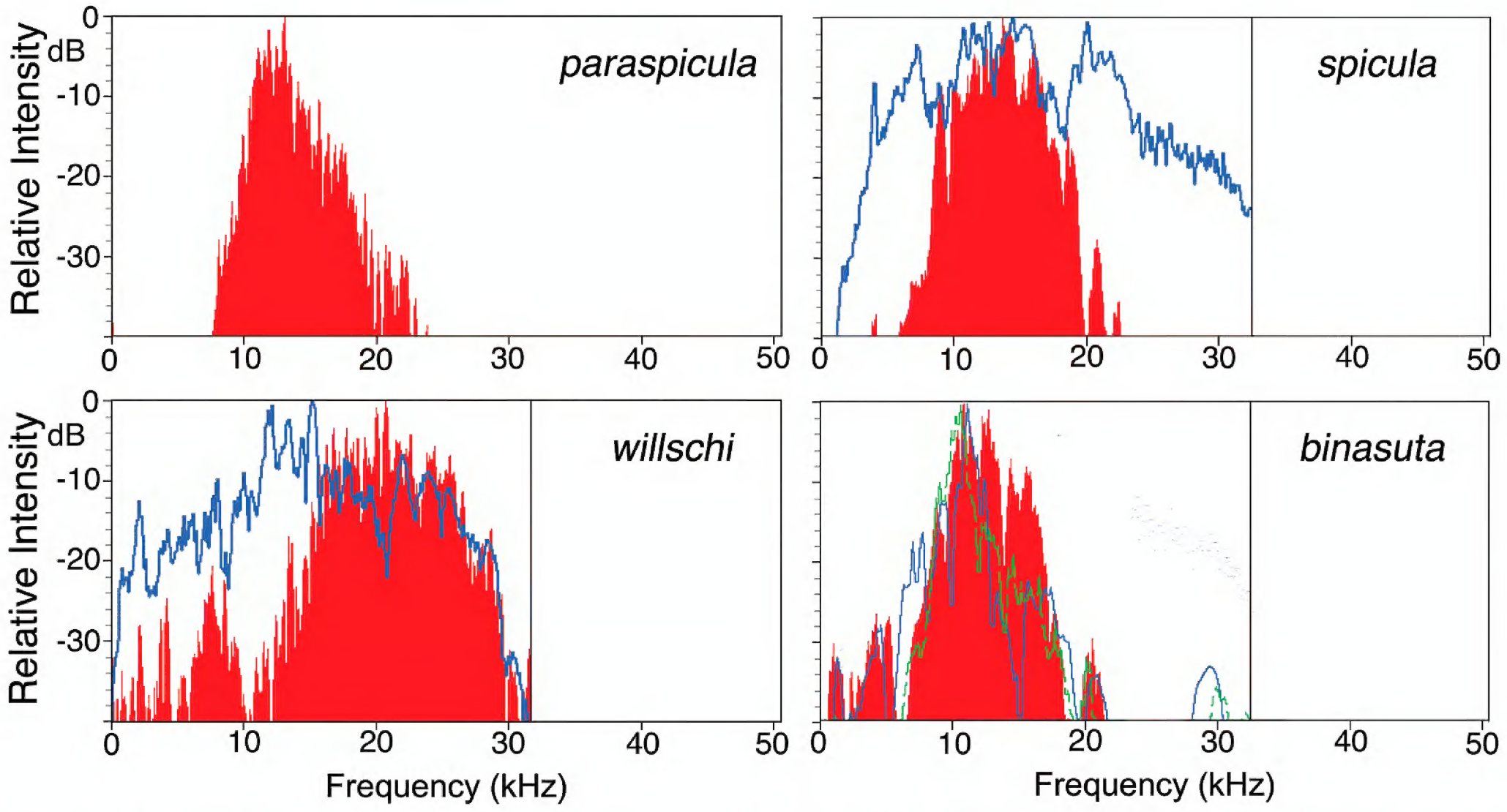

Fig. 11. Power spectra of male calling song of *Eurycorypha* species. In species with restricted frequency range, short black lines mark its end. Blue lines indicate power spectra of female responses, and the green broken line in *E. binasuta* indicates the power spectro of the short pulse-like male syllables.

The females responded only to the crescendoing group of syllables (first echeme type), always with a certain delay after the crescendoing syllable group (Fig. 12C, D). The latency was 334–362 ms (means of 3 females, n = 10 per female; T = 23–24°C) measured from the beginning of the echeme and 122–134 ms measured from the end of the syllable group. The responses were quite variable in amplitude modulation (see Fig. 12C, D for examples) and consisted typically of many impulses with different amplitudes and high-amplitude pulses.

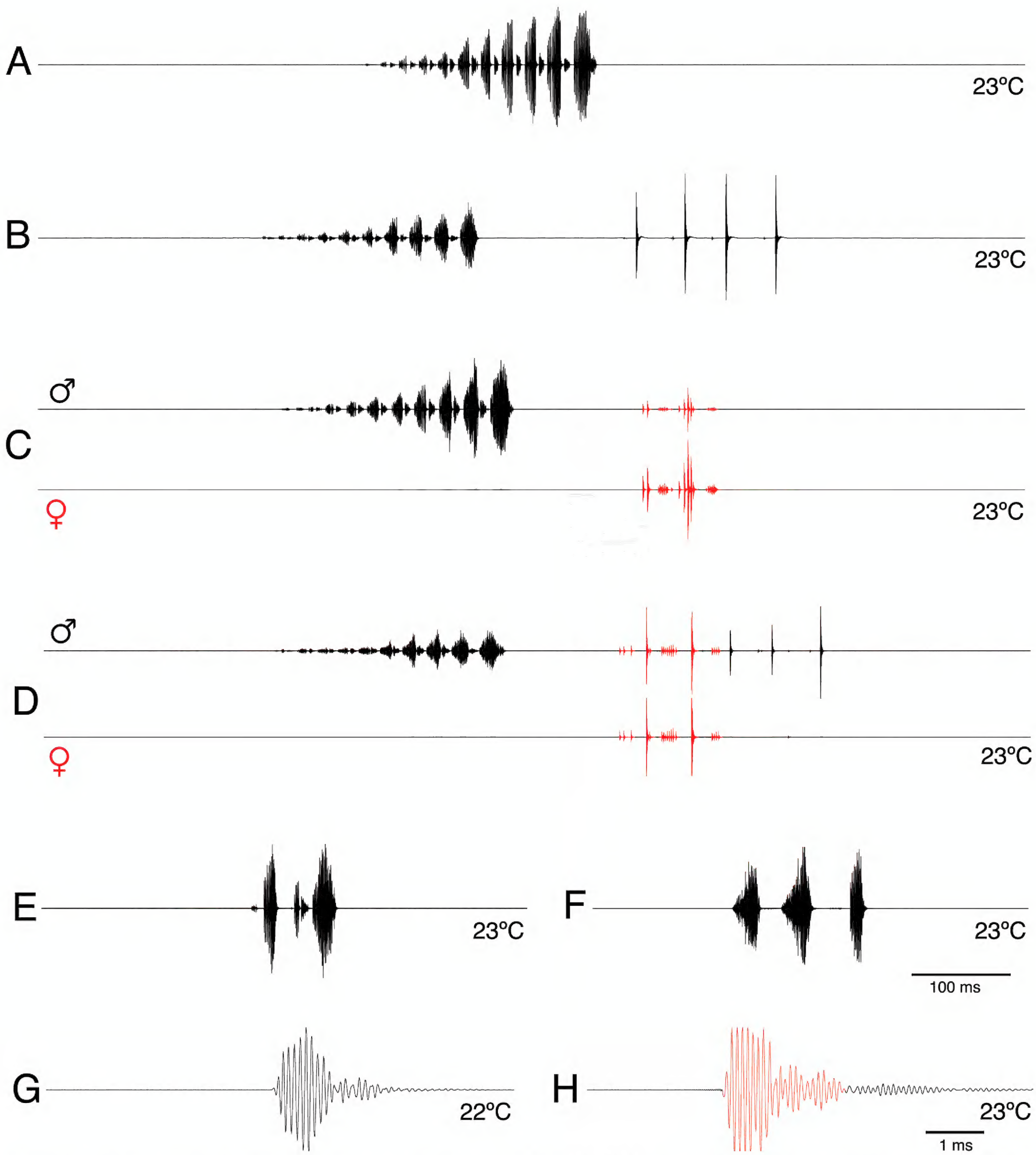

Fig. 12. Oscillograms of male echeme and male-female duets in *E. binasuta*, details (1 s sections). **A, B, E, F.** Different types of male echemes: **A, B.** Crescendoing group of syllables (sub-types A and B); **E.** Pairs of syllables, **F.** Triplet of syllables; **C, D.** Male–female duets; **G.** Male short pulse-like syllable; **H.** Female high-amplitude pulse.

Table 2. Body and spermatophore mass in *Eurycorypha* species.

Species	Male body mass		Female body mass		Spermatophore mass	Spermatophore mass	
	mg	n	mg	n	mg	% male body mass	n
Eurycorypha binasuta	483	2	722	2	80	16.6	1
Eurycorypha combretoides	485	4	740	4	40.75	8.4	4
Eurycorypha conclusa	322	1	504	1			
Eurycorypha elongata	676	1	584	1			
Eurycorypha flexata	698	1	776	1			
Eurycorypha ligata	333	2	474	2	14	4.2	1
Eurycorypha pianofortis	460	1	394	1	41		
Eurycorypha pseudovaria	550	4	834	2			
Eurycorypha varia	436	3	698	3	67	15.4	3
Eurycorypha willschi	500	2	604	4	51.5	10.3	2

The spectrum of the syllable group in the male song showed a relatively broad peak around 11 kHz; that of the pulse-like short syllables, however, had the same peak but a much smaller bandwidth. This narrow-banded spectrum closely resembled that of the females (Fig. 11; see Table 1 for other details).

Discussion

A survey of *Eurycorypha* specimens in various European entomological collections showed numerous new species awaiting description. Besides widespread species such as *E. willschi*, mostly of an elongate shape with little sexual dimorphism and inhabiting lowland forests, *Eurycorypha* has endemic species restricted to small, mostly mountainous areas. These endemic species, such as *E. paraspicula* and *E. spicula*, are typically rounder in shape and inhabit montane habitats. The latter two species occur in the Eastern Arc Mountains, which are known for their old age, high biodiversity, and endemism across many plant and animal taxa, including Orthoptera.

E. paraspicula and *E. spicula* likely became isolated during periods when forest cover was reduced, and they had to adapt to submontane and montane forests. Similar mechanisms were observed in the flightless coptacrine grasshopper genus *Parepistaurus* Karsch, which likely speciated along the Eastern Arc Mountains due to the aridification of Africa fragmenting a once continuous forest cover. During humid periods of the last 1–2 million years, the temporary expansion of forest cover allowed forest species to spread again, colonizing other areas with suitable habitats (Hemp et al. 2015). Although fully winged, this mechanism is also observed in *Eurycorypha*, particularly in taxa that are rounder and not very flight-active. *Eurycorypha* species inhabiting savanna woodlands are more widespread, reflecting the extension of their habitat, such as *E. combretoides* Hemp, 2013 in eastern Africa and *E. willschi* occurring in lowland forests that were once widespread in central and western Africa. Climatic fluctuations in the past fragmenting and reconnecting forest cover seem to have driven speciation in *Eurycorypha*.

Concerning bioacoustics, *Eurycorypha* belongs to the few tettigonioid genera with a very high intra-generic diversity of song patterns (Heller and Hemp 2020). It may surpass similar genera like *Dioncomena* (Hemp et al. 2023) or *Ducetia* (Heller et al. 2017) in the number of different song types, taking into account that the sounds of many species are still unknown. Confirming this assumption, the song patterns of the three species studied here were all new to the genus and did not overlap with previously known patterns, except possibly for *E. paraspicula* and *E. binasuta*.

E. paraspicula has the most simple song of the three, but it is nevertheless different from all other species previously known. It is somewhat similar only to the song of *E. binasuta*, described here in more detail. Both species differ slightly in SRR (41 versus 32.5 Hz). The acoustic response behavior of *E. paraspicula* females is still unknown. The song of *E. spicula* is more complex, with an unusually long syllable at the beginning of each echeme. It is not easy to determine if this unusual characteristic is used for triggering the female answer. Females ready to mate typically respond after the end of an echeme but quite variably and sometimes so shortly that the answer cannot be triggered by the end of the echeme (as known from, e.g., *Isophya stepposa*; Zhantiev and Korsunovskaya 1986). Interestingly, a male may try to disturb the duet of a rival by producing a special type of syllable series (see Fig. 9C) at the time a response is heard or expected. Similar interactions have been observed in *Eurycorypha varia* and *E. pseudovaria* (Heller and Hemp 2020). Acoustical defenses of the duet (see below) were not observed. Finally, *E. willschi* has a relatively simple-looking song. However, the male produces a series of two types of echemes. Slow echemes—pairs of syllables—are also found in the songs of several other *Eurycorypha* species (e.g., *E. elongata*, *E. ligata*, *E. binasuta*; Heller and Hemp 2020). Their function is unclear, but they were never answered by females. All these species also have another type of echeme to which the females respond. These echemes are typically much more complex than pairs of syllables but are surprisingly similar in *E. willschi*, differing mainly in SRR. A series of these fast echemes typically starts with a distinctly lower amplitude than the preceding slow echemes. The females respond to these soft signals, which may be less obvious to rivals. A similar situation can be observed in *Eurycorypha pianofortis* (see Heller and Hemp 2020) and *Anaulacomera almadaenis* (Heller et al. 2020). In addition, the males 'defend' the duet by producing female-like sounds (Figs 9F, 12D), making recognition and localization by rivals more difficult. Interestingly, in *E. binasuta*, the male signals are similar to those of the females not only in timing but also in spectral properties (Fig. 11). This resemblance may be the result of biophysical constraint on producing short high-amplitude sounds with a necessarily resonant structure, but it could also be based on selection for spectrally most female-like male signals, as in *Gonatoxia* (Heller and Hemp 2017).

The discovery of these three new song patterns supports the expectation that, among the many bioacoustically unstudied and the undescribed *Eurycorypha* species, many fascinating songs and duets might be found.

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